Long-Range Forecasting and Climate Research

Development of a Sahel rainfall series using CLIMAT data

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1. INTRODUCTION

The time series of annual Sahel rainfall data produced by Nicholson(1985) has been used extensively by the UK Meteorological Office Synoptic Climatology branch for research into the physical causes of variations in seasonal Sahel rainfall. However this series is only available until 1984 and its constituent stations are not known, though the area represented by the series is known(fig 1).

A new series has been developed by the synoptic climatology branch of the UK Meteorological Office using CLIMAT data, publications by local meteorological services and SYNOP data, and has been made as homogeneous as possible with the Nicholson series. The new series uses WMO reporting stations and can therefore be readily updated each year. A survey of station rainfall data available in the Meteorological Office showed that there are very few before 1951. Hence the new series is constructed from 1951 onwards. The current version of the series has most stations in the central and west Sahel. However this problem, while needing further attention, is not severe as shown by the good correlation between the new series and the Nicholson series.

2. SELECTION OF THE STATIONS

2.1. Definition of the Sahel

It was decided to define the Sahel to be as similar as possible to Nicholson's definition so that new years could be added to the Nicholson series with minimum adjustment, thus allowing continued use of Nicholson's longer series.

Nicholson's series was derived using stations where the annual mean rainfall total over the period c.1920-73 was between 100 and 450 mm. These stations defined the Sahel region displayed in fig 1.

2.2. Criteria used to select stations

A CLIMAT data station list and a map of African stations were used to identify 53 candidate stations within or very close to Nicholson's Sahel region.

Monthly mean rainfall values for the period 1951-present were examined for these stations. A number of them were omitted since they had a large amount of data missing. All candidate stations in Chad were omitted since they have not reported to us since 1978.

The stations chosen were mainly from major towns where station closure is unlikely and written records from these stations are nearly complete.

The time series can only be updated promptly if the data are regularly transmitted as CLIMAT reports on the GTS. Written publication of the data is

often a year or two after the event. Hence stations with few recent CLIMAT reports were not used.

Stations with annual mean rainfall for 1951-80 well above 450 mm or below 100mm were not accepted except for some 'near miss' stations (rainfall between 75mm and 550mm) which are located in areas of low station density in the central and east Sahel.

Fig.1 and Table 1 show the stations chosen for our series.

3. DATA SOURCES

3.1 Historical Data Sources (1951-87)

A preliminary dataset of monthly rainfall totals was set up using CLIMAT data for the chosen stations. However there are many gaps in the CLIMAT data, so rainfall statistics published by local meteorological services were used to fill these gaps and were also sometimes used to replace CLIMAT data.

The Sudan Meteorological Service has published data for a large number of stations in Sudan dating from 1951 to 1985. Five Sudanese stations were used which are well distributed within the Sudanese Sahel and have complete records back to 1951. The majority of data for 3 of the stations were collected from the CLIMAT archive and gaps filled using the Sudan Meteorological Service data. Data for the remaining 2 stations were obtained entirely from Sudan Meteorological Service publications from 1951 to 1985 since there were many gaps in the CLIMAT record for these stations. Sufficient data from all these stations are available from CLIMAT reports for updating the series from 1986 onwards.

The 'Comite Interafrican d'etudes hydrauliques' on behalf of the French government have published extensive data for the other Sahel nations. These data are from 1951 to 1965. Annual totals from these records were almost complete and were used in preference to the CLIMAT record in the production of the annual Sahel Rainfall index described below.

Gaps in the CLIMAT record for the non-Sudanese stations from 1966 to 1979 and from 1980 to 1983 were filled with data published by ASECNA, Dakar and and with data from reports written by local meteorological services respectively.

A written request was made in November 1987 to relevent national meteorological offices for data to fill gaps in the monthly station data since January 1984. A complete record for this period is important since the Nicholson series ends in 1984. Replies to this request have enabled us to fill all but a very small number (about 15 monthly mean values) of the gaps in the CLIMAT record from 1984 to 1987.

3.2 Real Time Data Sources (1988)

All 1988 data have been obtained from CLIMAT and SYNOP reports. There are 50 gaps in the CLIMAT monthly data for this year. 20 of these gaps were filled completely or partially using daily SYNOP data. These data are of poorer quality than the monthly reports but have proved very useful in filling gaps until better quality data arrive. In particular, since these data are available 2 days after the event , these data have enabled us to keep a day to day check on the progress of the 1987 and 1988 Sahel rainy seasons.

Gaps in the daily record for a given month were filled using the normal daily total calculated from the monthly normal if less than 20% of the data were missing, otherwise the gaps were filled by estimating the monthly total using the interpolation process described below and then dividing this estimate by the number of days in the month to make an estimate of the daily total.

4. INTERPOLATION OF THE MISSING DATA

The CLIMAT and local meteorological service reports provided an almost complete record of monthly rainfall totals from 1951 to 1980. However there were 4 gaps in the record for this period and 76 gaps in the record for 1981 to 1988.

Monthly normals and Standard deviations were calculated for each station using all observations available during the period 1951-80. Every normal and standard deviation value was calculated using at least 29 monthly totals out of a maximum of 30.

These normals and standard deviations were used to convert every monthly rainfall total from every station to normalised units. ie. by subtracting the normal (mean) and dividing by the standard deviation. Hence each station is treated equally despite differences in normal rainfall totals and variability.

Since the Sahel is known to be coherent in its rainfall distribution (Kraus 1977) and the objective is to produce an index of Sahel rainfall as a whole, gaps were filled according to the general wetness in the Sahel as a whole. The mean normalised anomaly for all the stations with data for a given month was used to fill any gaps for that month. The normalisation process was then reversed to produce a rainfall estimate. Monthly totals calculated using daily SYNOP reports were used in this calculation provided the daily data are at least 80% complete. Data coverage is at least 90% for each month, hence the interpolations always give a good indication of Sahel rainfall as a whole.

In the 4 cases when less than 30 monthly totals were used to calculate the normals and standard deviations because of a data gap, the normals and standard deviations were recalculated with the gap filled using the estimate described above.

5. PRODUCTION OF THE ANNUAL SAHEL RAINFALL SERIES

A series was then produced by

a) Calculating annual rainfall totals for each station

b) Calculating the mean and standard deviation of annual rainfall for each station over the period 1951-80.

c) Converting the annual rainfall values to normalised units using these means and standard deviations in order to give equal weight to each station.

d) Averaging the normalised series of the 27 stations to form a Sahel series.

It is also possible to calculate Sahel indices for individual calender months or combinations of months and for subsets of Sahel stations.

6. MERGING THE MET O 13 SERIES WITH THE NICHOLSON SERIES

The equation

$$am_j' = \left(am_j \times \frac{\sigma_n}{\sigma_m}\right) + \overline{an} - \overline{am} \qquad \text{for year } j$$

where σ_n is the standard deviation of the Nicholson series, σ_m is the standard deviation of the Met O 13 series, $\overline{an}$=mean of the Nicholson series and $\overline{am}$=mean of the Met O 13 series over the period 1951-80 was used to make the Met O 13 series(am_j) compatable with the Nicholson series (an_j). The adjusted Met O 13 series(am_j') has the same mean and standard deviation as the Nicholson series over the period 1951-80. The two series are shown in fig.2.

The correlation between the Met O 13 series and the Nicholson series over the period 1951-84 was 0.97. Hence Met O 13 values for 1985 and 1986 were used to extend the Nicholson series.

REFERENCES

ASECNA (1966-1979) Monthly Summary of Surface Observations Annexe pluviometrique

Comite Inter-African D'etudes Hydrauliques, France. Precipitations Journalieres de L'origine des Stations a 1965 (For Niger, Mali, Mauritania, Senegal)

Kraus E.B. (1977) Subtropical droughts and cross-equatorial energy transports. Mon. Weather. rev., vol 105, p 1009-1018.

Nicholson S.E. (1980) The nature of rainfall fluctuations in Sub-tropical West Africa. Mon. Weather. rev., vol 108, p 473-487.

Nicholson S.E. (1985) Sub-Saharan rainfall 1981-84. J. Clim. Appl. Met., 24, p 1388-1391.

Sudan Meteorological Service Monthly Rainfall Statistics 1951-1987

TABLE 1: STATIONS USED TO MAKE MET 0 13 SERIES

Station Name	Country	Number	Lat (N)	Long (E)	Elev (m)	Data Source
Agadez	Niger	61024	16.58	7.59	503	A
Tillabery	"	61036	14.12	1.27	210	A
Tahoua	"	61043	14.54	5.15	387	A
N'Guigmi	"	61049	14.15	13.07	286	A
Zinder	"	61090	13.47	8.59	453	A
Maine-Soroa	"	61096	13.14	11.59	339	A
Kidal	Mali	61214	18.26	1.21	459	A
Tombouctou	"	61223	16.43	3.00W	264	A
Gao	"	61226	16.16	0.03W	260	A
Hombori	"	61240	15.20	1.41W	288	A
Menaka	"	61250	15.52	2.13	278	A
Mopti	"	61265	14.31	4.06W	272	A
Nouakchott	Mauritania	61442	18.06	15.57W	3	A
Tidjikja	"	61450	18.34	11.26W	402	A
Boutilimit	"	61461	17.32	14.41W	75	A
Rosso	"	61489	16.30	15.49W	6	A
Nema	"	61497	16.36	7.16W	269	A
Kiffa	"	61498	16.38	11.24W	115	A
Aioun el Atrouss	"	61499	16.42	9.36W	223	A
St Louis	Senegal	61600	16.03	16.27W	4	A
Podor	"	61612	16.39	14.56W	7	A
Matam	"	61630	15.39	13.15W	17	A
Khartoum	Sudan	62721	15.36	32.33	380	B
Wad Medani	"	62751	14.24	33.29	408	C
El Fasher	"	62760	13.37	25.20	730	B
El Obeid	"	62771	13.10	30.14	574	B
Kosti	"	62772	13.10	32.40	381	C

Key To Data Sources for Annual series

A Asecna, Dakar 1951-65, Comite Inter-African D'etudes Hydrauliques 1966-79, National Meteorological Service reports 1980-87, CLIMAT Reports 1966-88, SYNOP reports 1988.

B Sudan Meteorological Service monthly rainfall statistics 1951-87, CLIMAT Reports 1951-88, SYNOP reports 1988.

C Sudan Meteorological Service monthly rainfall statistics 1951-87, CLIMAT reports 1988, SYNOP reports 1988.

FIGURE 1: SAHEL BOUNDARY AND

STATIONS USED TO MAKE MET O 13 TIME SERIES

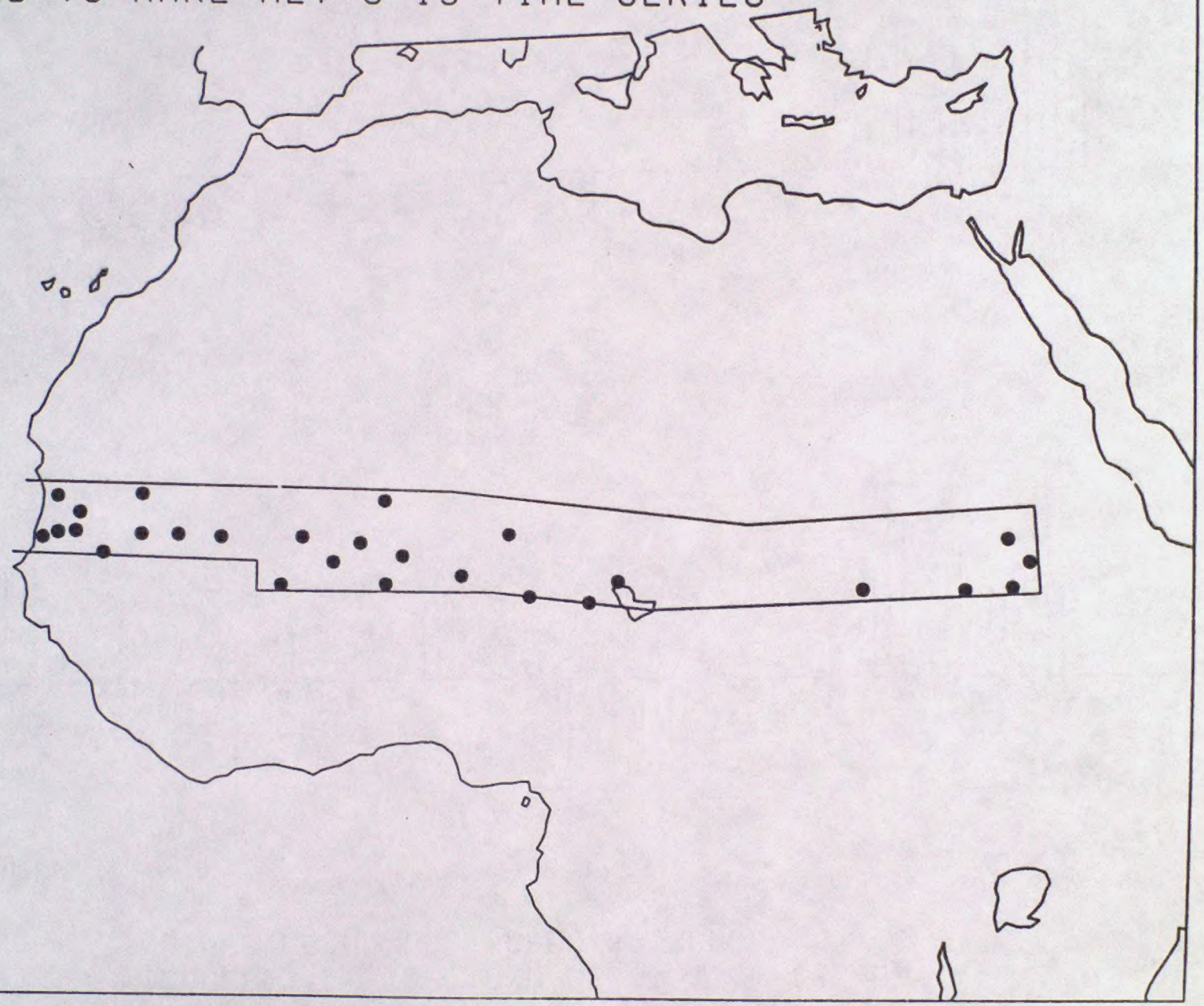
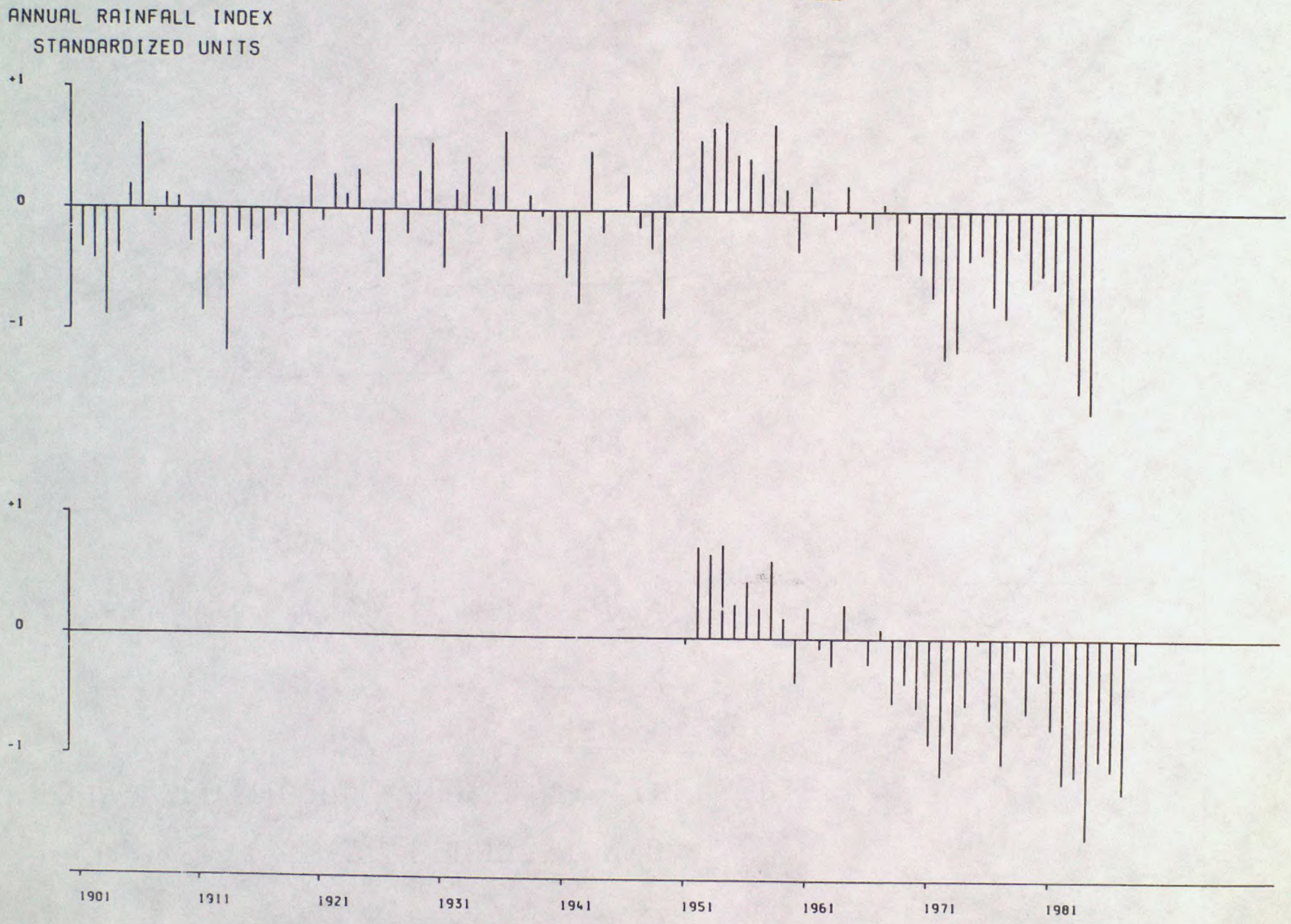
FIGURE 2: NICHOLSON'S (TOP) AND MET O 13'S (BELOW)
INDICES OF ANNUAL SAHEL RAINFALL